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Get ClimateReady – What is meant by sea level rise?

Description

This month, as part of our Get ClimateReady campaign, we will be exploring the theme of sea level rise, a topic which has been of significant interest this year. Simply put, “sea level rise” refers to the rise in the ocean surface as a result of climate change. Rising sea levels can cause significant impacts for infrastructure, coastal communities and wildlife across the globe, and it is clear that a combined approach, implementing both mitigation and adaptation measures, is necessary to avoid the worst of these impacts. Understanding the changes in sea level – what causes them, why, and how quickly they occur, is imperative if we are to adopt the most effective solutions.

There are two main aspects of sea level rise that are of particular interest to climate scientists:

Global and regional mean sea level
Increases in global mean sea level are caused by two main processes; thermal expansion of oceans as they increase in temperature due to global warming, and the addition of more water to the oceans – mostly from melting ice sheets and glaciers.

Whilst the total increase in ocean volume relates to global mean sea level rise, regional sea level can be influenced by additional factors such as changes in ocean currents, the distant effects of land ice melt and the rise and fall of land masses. These factors affect sea level rise around the UK. For example, while the land is rebounding in Scotland after the last ice age, in southern England it is sinking, which affects the sea level rise experienced in these regions.

Similarly, gravitational effects can influence sea level at a regional scale. The large amount of ice in the Greenland and Antarctic ice sheets means that water is pulled towards them by gravity. As this ice melts, the gravitational attraction decreases, which leads to a drop in sea level near the ice sheet and a

rise much further away. Areas that are in between the areas of fall and rise experience very little sea level rise from the ice sheet melt. Due to its geographic location, melting of the Greenland ice sheet will have a much lesser effect of UK sea level rise than melting of the Antarctic ice sheet.

In this article from the Guardian, Met Office Climate Scientist Dr Matt Palmer explains more about the gravitational effects which influence sea levels.

Extreme sea level
Extreme sea level typically refers to the maximum sea level that is experienced during a storm. Storm surges can contribute to significant extremes in sea level, occurring when sea levels rise due to a combination of a reduction in atmospheric pressure, water being forced onto the coast by the wind, and in some cases funnelling by the local bathymetry (variations in the ocean floor).

Climate change and sea level
As the planet warms, so too do our oceans, directly contributing to thermal expansion and the melting of ice sheets and glaciers, which lead to increases in global and regional mean sea level rise. The slow response of the oceans and ice sheets to climate change mean that sea level will continue to rise for centuries, even under scenarios where future temperature rise is stabilised/stopped.

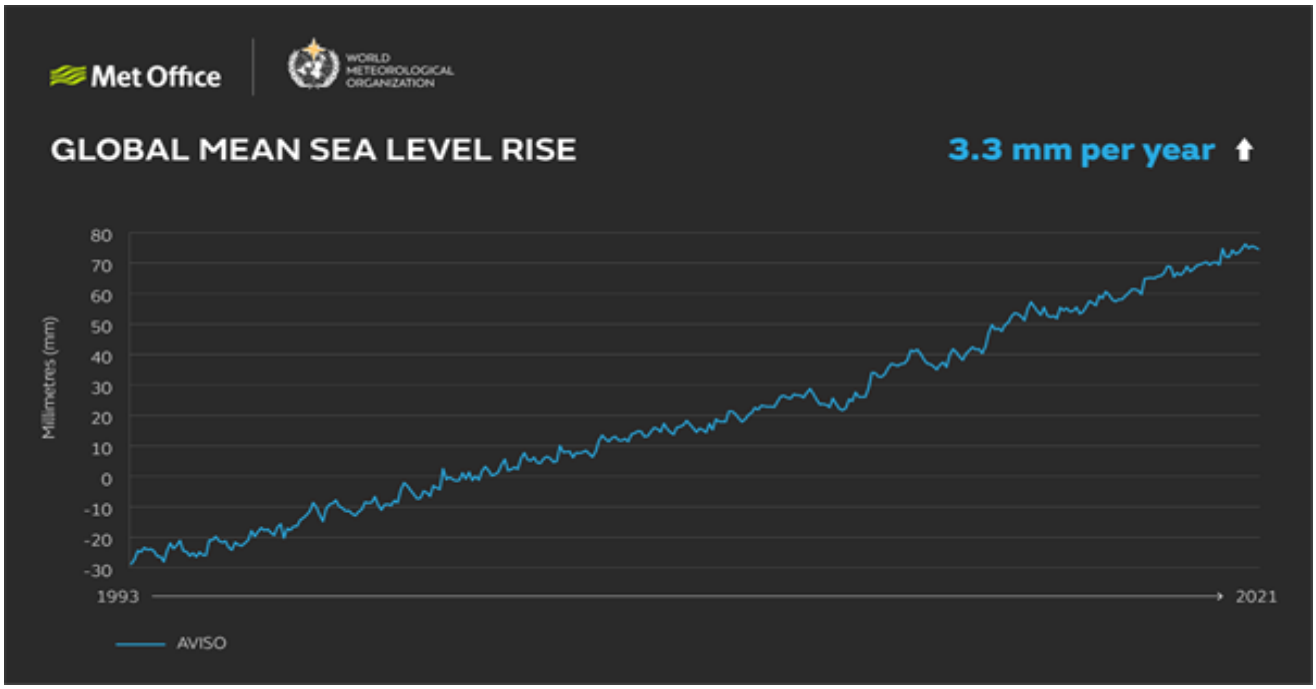
The Intergovernmental Panel on Climate Change (IPCC) is the United Nation's body for assessing the science related to climate change. In August 2021, the IPCC published the Working Group 1 (WG1) contribution to the Sixth Assessment Report (AR6), a peer-reviewed publication which examines the physical science of climate change, based on contributions from thousands of international scientists. The report confirmed that global mean sea level has increased by 20cm since the early 20th century and that human influence was the main driver of these increases since at least the 1970s. Extreme sea level events are also expected to become more frequent in the future and IPCC assessed that, compared to the recent past, extreme sea levels will occur about 20 to 30 times more frequently by the year 2050.

Met Office
IPCC REPORT HEADLINE FINDINGS
Greenhouse gas impacts
Many changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level.

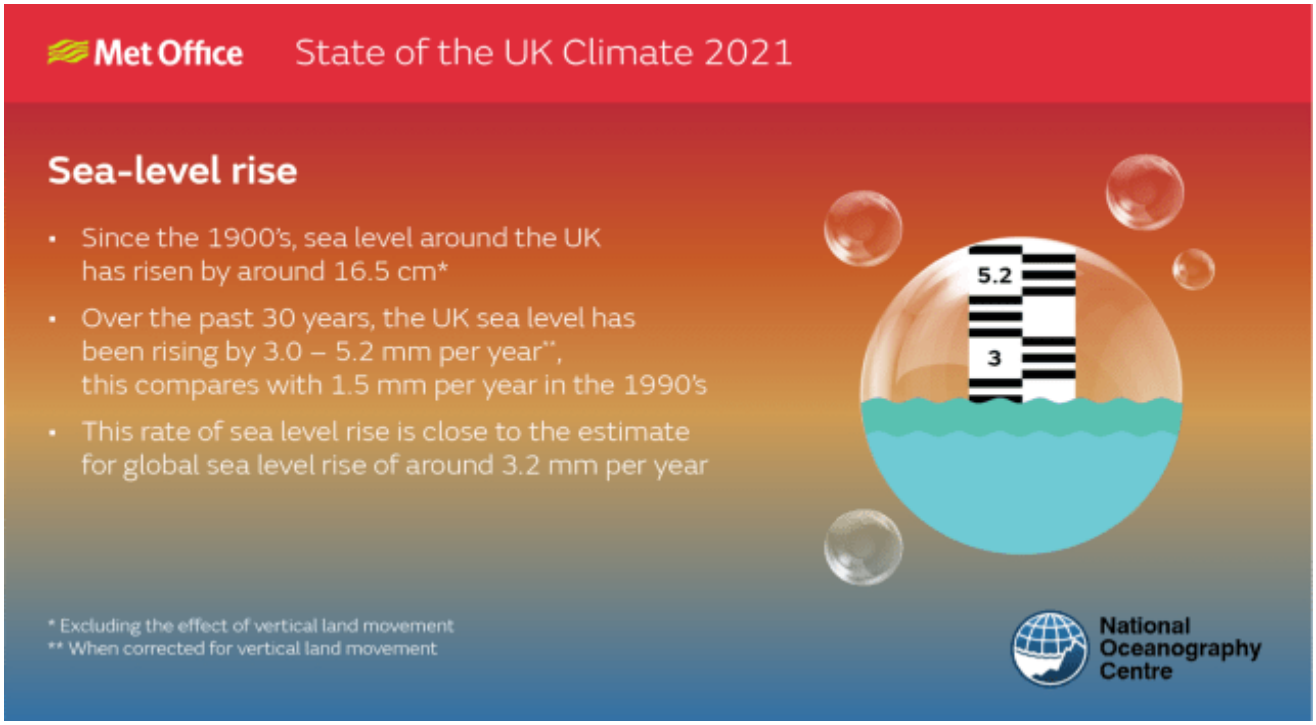
Dr Helene Hewitt, of the Met Office, was a co-ordinating lead author on the chapter covering Oceans, Cryosphere and Sea Level. In an article exploring the findings of the IPCC's report, Helene took a closer look at what we know about past and future sea level rise, and examined projections for the future, based on different climate scenarios.

Speaking about the report, she said:
"This report demonstrates that oceans are continuing to warm, ice is melting and sea level is rising. Many of these changes will not stop immediately if we reduce emissions but they can be slowed down and crucially, we will limit the risk of rapid ice loss from Antarctica which otherwise could lead to additional metres of sea level rise over the coming centuries".

More recent climate reports provide further clear evidence to support the fact that climate change is influencing sea levels, both around the UK and across the globe. Published in May, the World Meteorological Organisation's State of Climate report found that global mean sea level reached a new record high in 2021. The report confirmed the IPCC's findings that the rate of sea level rise had increased, estimating that sea level has risen at an average rate of 4.5mm per year over the period 2013 – 2021, more than double of that between 1993 – 2002. Such an increase can be attributed to the accelerated loss of ice mass from ice sheets.



The increasing rate of sea level rise seen in the global mean is also apparent in regional sea level around UK. The latest State of the UK Climate report for 2021 by the Met Office, found that the rate of sea level rise around the UK is increasing, with selected locations seeing a sea level increase of 3.0-5.2mm per year, compared to around 1.5mm per year in the 1900s.


Met Office
State of the UK Climate 2021
Sea-level rise
Since the 1900's, sea level around the UK has risen by around 16.5 cm*
Over the past 30 years, the UK sea level has been rising by 3.0 – 5.2 mm per year**, this compares with 1.5 mm per year in the 1990's
This rate of sea level rise is close to the estimate for global sea level rise of around 3.2 mm per year
5.2
3
* Excluding the effect of vertical land movement
** When corrected for vertical land movement
National Oceanography Centre

The National Oceanography Centre (NOC) provided the input for the sea level section of the State of the UK Climate report.

Dr Svetlana Jevrejeva, a Principal Research Scientist at the NOC, said:
“Our long-term records show that over the past few decades, rate of sea level rise in the UK is increasing. As sea levels rise there can be greater impacts from storm surges. Last year storm surges of over 1.5 m were seen during Storm Arwen, but extreme sea levels were avoided as this occurred during low water and a neap tide”.

Throughout August we will be continuing to explore the topic of sea level rise and its wider impacts. In our next blog, we’ll be taking a closer look at sea level rise – how it is monitored, the impacts it can cause, and the different approaches that can be taken to mitigate these, both here in the UK and from a global perspective. Follow #GetClimateReady on Twitter as we explore the topic of ‘sea level rise’.

Get ready for tomorrow #GetClimateReady

Date Created
August 2022

How will the summer end: ‘bang’ or ‘whimper’?

Description

The summer 2022 has been remarkable on many fronts, says Paul Davies Met Office Fellow (Meteorology).

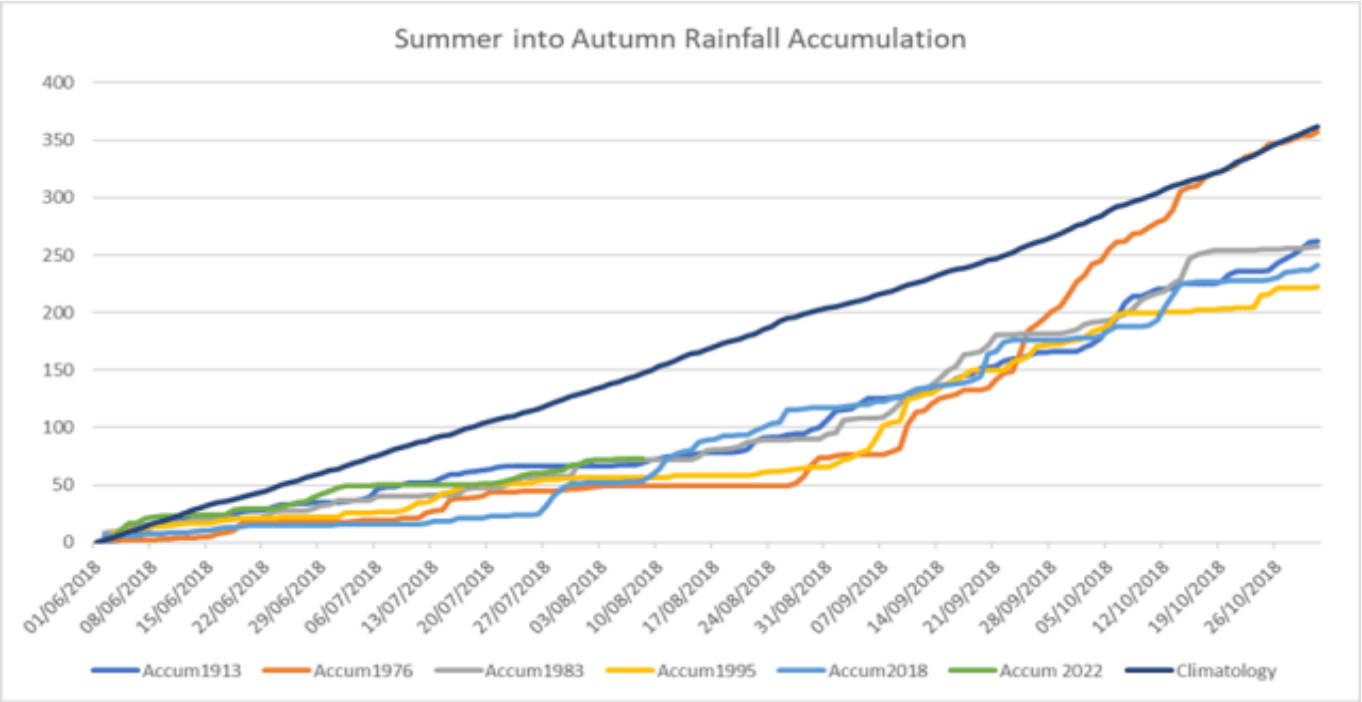
We exceeded the 40°C threshold for the first time ever, and for England the January-July period has had 69% of average rainfall making it the ninth driest in a series from 1836, and the driest such period since 1976.

July was also the driest July for England since 1935 and the driest on record for East Anglia, southeast and southern England. Some locations, such as Odiham in Hampshire, have received little or no rain since 30th June.

What does this mean for the rest of summer and beyond? Is there anything we can glean from previous heatwaves or long-lasting periods of dry weather?

Below is a plot of rolling rainfall accumulation from 1 June to 31 October for the five driest summers on record (1913, 1976, 1983, 1995, 2018) compared to the average for the period 1991-2020. Meteorologists refer to this as the climatological average.

1976 and 1995 were notable for having a sharp transition to wet conditions in September, and to a slightly lesser extent 2018 in July and August. It is also noticeable how quickly rainfall recovered to average during early autumn 1976, and the preceding heavy rain and excessive flooding from mid-August.



Why do we see these sudden changes in weather patterns? To help us explain this we need to see the weather world through regimes. A regime is a persistent state of the atmospheric circulation which can be ascribed to a weather type, for example a regime may consist of a strong Atlantic Jet bringing a series of low-pressure systems, wind, and rain across the UK. Storms Dudley, Eunice, and Franklin were classic examples. Or it might be an area of high pressure leading to long periods of dry conditions and warmth.

In 1976, the regime pattern got stuck, with a persistent area of high pressure locked in across the UK for most of the summer. But then, remarkably, the regime abruptly changed within a few days to a more unsettled type with rain and thunderstorms. High pressure – with its associated heatwaves – has been the dominant regime affecting the UK during this summer, but what does the future hold as we transition into autumn.

To try to answer these and similar questions, the Met Office has been developing a tool, called Decider to identify and forecast regimes.

Decider is based on our ensemble system – which produces multiple forecasts with different starting points aiming to capture the ‘chaotic’ nature of the weather and express the answer as probabilities.

Using Decider, we can infer the regime type for this and the following week in the plot below. It suggests a change of regime next week from hot and dry associated with a high pressure regime (red colours) towards a pattern that is typically associated with low pressure (blue): less hot with a chance of showers and thunderstorms. The numbers in the boxes representing the probability and therefore reflecting the confidence in how one regime changes to another. So, what does that mean for the UK?

Probabilistic Pressure Trend

	Fri 12 Aug	Sat 13 Aug	Sun 14 Aug	Mon 15 Aug	Tue 16 Aug	Wed 17 Aug	Thu 18 Aug	Fri 19 Aug	Sat 20 Aug	Sun 21 Aug	Mon 22 Aug	Tue 23 Aug	Wed 24 Aug	Thu 25 Aug	Fri 26 Aug
Latest model run (12/00 UTC)	100%	94%	100%	100%	96%	90%	43%	47%	47%	37%	55%	61%	39%	63%	80%
Previous model run (run -1)	100%	92%	90%	94%	69%	76%	43%	45%	41%	45%	43%	49%	43%	61%	75%
Previous model run (run -2)	100%	71%	92%	100%	55%	63%	41%	35%	41%	45%	37%	--	39%	45%	
Previous model run (run -3)	90%	78%	75%	98%	65%	71%	47%	49%	57%	53%	55%	49%	47%	47%	
Previous model run (run -4)	96%	55%	71%	92%	57%	51%	59%	65%	47%	41%	43%	43%	59%		
Previous model run (run -5)	92%	59%	55%	92%	51%	57%	53%	63%	45%	45%	43%	43%	51%		
Previous model run (run -6)	78%	65%	65%	71%	69%	53%	--	53%	35%	41%	41%	35%			
Previous model run (run -7)	76%	55%	53%	71%	55%	65%	51%	55%	43%	37%	39%	49%			
Previous model run (run -8)	63%	71%	55%	55%	55%	49%	45%	45%	39%	41%	43%				
Previous model run (run -9)	65%	71%	41%	47%	41%	49%	51%	47%	43%	63%	57%				
Previous model run (run -10)	84%	80%	55%	39%	--	43%	49%	--	43%	43%					

RED	Weather patterns typically associated with **high pressure** over the UK are most likely
GREEN	Weather patterns typically associated with **unbiased conditions** over the UK are most likely
BLUE	Weather patterns typically associated with **low pressure** over the UK are most likely
WHITE	Equal likelihood of two or three of the above tendencies occurring

(Above) The output from the Met Office Decider system helps forecasters understand when a weather regime change is most likely to occur. The reds for high pressure are clearly most likely to give way to a regime dominated by low pressure into next week.

Based on today's Decider forecast and medium-term forecasts, there is an increased chance of rain from early next week onwards. However, there is a question mark on duration, intensity and whether the wet pattern will continue into autumn.

For areas that have received none or very little summer rain, the question on what type of rain can we expect is important too. Especially as the Environment Agency has today confirmed drought status for eight of its 14 areas in England.

Will the rainfall suggested by the forecast be sufficient to shorten the duration of the drought? We will have to see, but the door is open to a forecast with more rainfall for southern England than we have seen since early June.

In the next seven days the forecast though has a lot more certainty. Providing the Met Office with sufficient confidence to issue thunderstorm warnings covering the greater part of the UK. The rain could be of sufficient intensity to result in high-velocity flows, flash flooding and debris as slow-moving thunderstorms deposit rain onto baked, hardened surfaces with water running off into potential downstream deluges.

This will it be a 'hit-and-miss' affair with locations only a few miles apart receiving no rain while others seeing extreme rainfall and flooding.

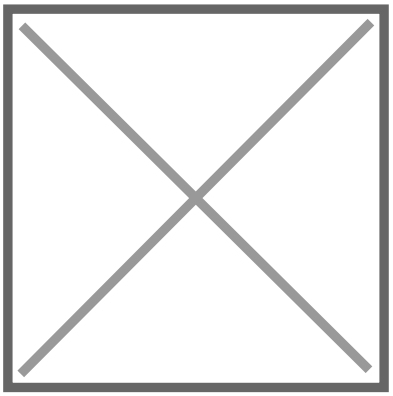
Before assessing the longer-range forecast into the rest of August and September, we may have to

wait until the Atlantic Jet strengthens. This will be driven in part by the decaying remnants of hurricanes entering our latitude; driven in turn by an anticipated active hurricane season. At this range, indications remain mixed, highlighted in lower probabilities in the Decider plot above, but there are signs for further spells of wind and rain across the UK, especially across more northern and western areas with occasional incursions further south and east.

Back to the question: how will the summer end?

For some next week the summer will end with a ‘bang’ as intense thunderstorms are forecast for early next week, while others who miss the rain will perceive the change as a ‘whimper’.

Date Created
August 2022



Monitoring and responding to sea level rise

Description

In our recent blog post, we introduced our August climate theme of sea level rise, explored some of the different aspects, and looked at how climate change can influence sea levels at a global and regional scale. In this blog, we will be taking a closer look at this topic to find out how sea levels are monitored and the actions that can be taken in response to changing sea levels.

Monitoring sea level rise
Climate scientists monitor sea levels to understand how they have changed over time, and to inform projections of how they might change in the future and the impacts that these changes might cause. Sea level is monitored by tide gauges and from space by satellites.

The Global Climate Indicators are a set of parameters that describe the changing climate, looking beyond temperature as the only indication of climate change. They comprise key information for the most relevant domains of climate change: temperature and energy, atmospheric composition, ocean and water as well as the cryosphere. These indicators provide additional information and allow a more detailed picture of changes to our climate.

The Met Office climate dashboard provides a comprehensive way to stay up to date on the current state of the climate by providing data based on observations of these key global climate indicators, one of which is sea level rise.

Nick Rayner, who leads the Met Office's Climate Monitoring team said of the dashboard: "Observations from coastal tide gauges show sea levels rose by nearly 200mm between 1900 and 2000. However, by building in projections of sea level rise linked to different scenarios for future greenhouse gas emissions, you can easily see what we are already committed to and the need for urgent action to minimise further changes."

You can view the sea level dashboard here.

How much could sea levels rise?
In August 2019, the Met Office Hadley Centre produced a set of UK- focused sea level projections for a

report which was published by the Environment Agency. The projections demonstrated that under all emissions scenarios, sea levels would continue to rise well beyond the year 2100, although the rate and severity of the rise would depend on the level of emissions.

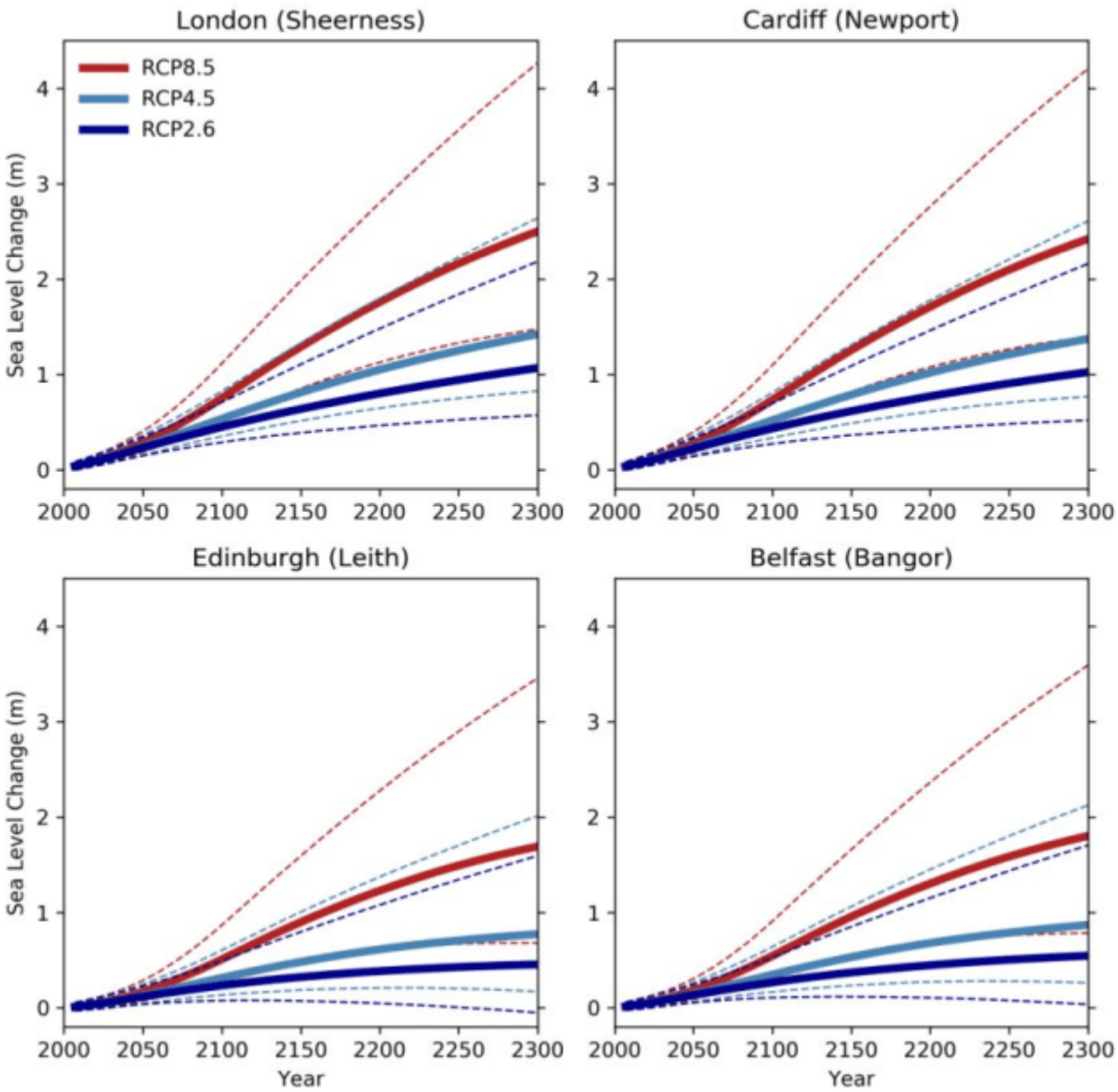


Figure 1. Time series of the time-mean relative sea level change for UK capital cities based on the nearest Class A tide gauge location (indicated in brackets). Notes: Solid lines indicate the central estimate and dashed lines indicate the 5th to 95th percentile range for each RCP scenario as indicated in the legend (top left panel). All projections are presented relative to a baseline period of 1981 to 2000. Source: UKCP18 Marine Report (Palmer et al. 2018b, Figure 3.1.4)

Matt Palmer, who leads the sea level projection work at the Met Office said: “As part of the UKCP18 national climate projections, we developed a new set of sea level projections with information available all the way to 2300. These longer time horizons are needed to fully appreciate the future sea level rise

we will need to adapt to under different amounts of future climate change. Even under immediate and sustained reductions of greenhouse gas emissions, the UK will need to be prepared for 1-2 m of future sea level rise."

Sea level rise impacts

Rising sea levels can cause a myriad of impacts, from changing the shape of our coastline and beaches, to threatening infrastructure and the homes of people who live in coastal communities. Rising sea levels can also threaten the survival of already fragile wildlife habitats.

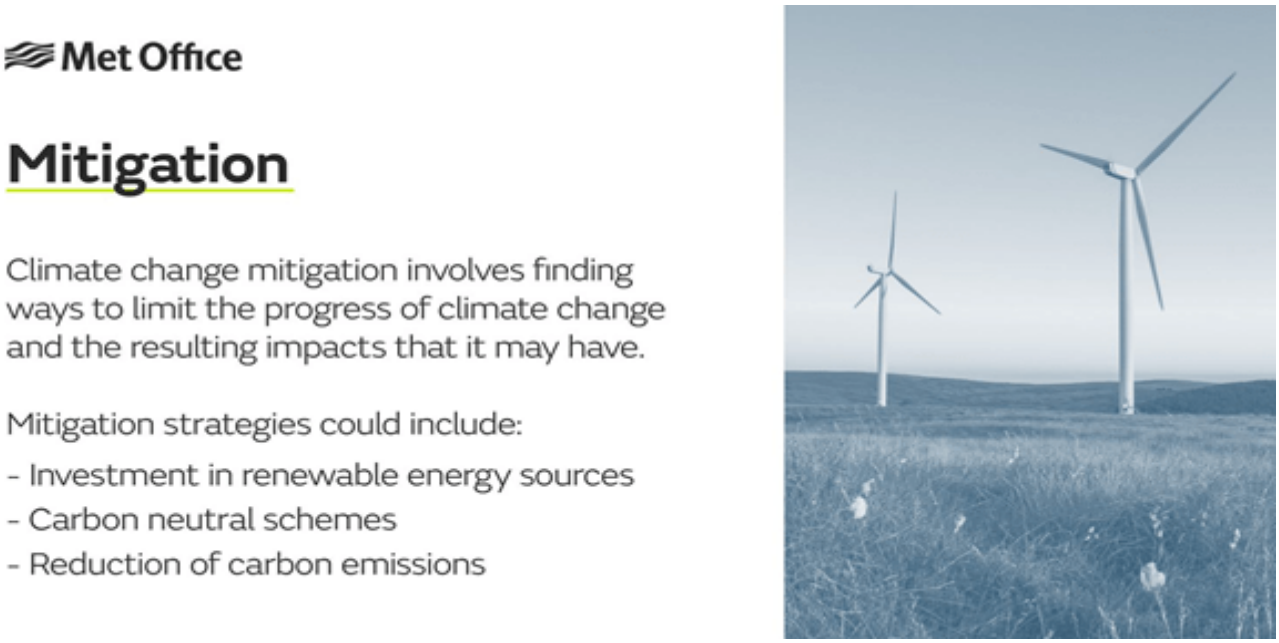
As the sea level rises around the UK it exposes more areas of coastal land to larger and more frequent storm surges and wind-driven wave impacts. In February 2014, a storm destroyed a section of the seawall in Dawlish, Devon, leaving the railway line suspended in mid-air. This line was the only one linking Cornwall to the rest of the country, so its damage caused significant travel disruptions. Reconstruction of the sea wall and train line cost millions of pounds, and it wasn't until April 2014 that the line was reopened.

Major infrastructure close to the sea such as the main Devon to Cornwall rail link at Dawlish will be increasingly vulnerable to rising sea levels and storm surges.

Tackling sea level rise – a combined approach

Research tells us that climate change influences sea level rise, and we know that even if we were to curb emissions of greenhouse gases, we are already committed to substantial sea level rise over the coming century and beyond, based on the concentration of greenhouse gases that are already in the atmosphere. With this in mind, how can we respond to the threat of rising sea levels, and is there anything that can be done to limit this progress? The answer lies in a combined approach.

Mitigation will be a vital strategy in stabilising the rate of climate change-induced sea level rise. Climate change mitigation involves finding ways to limit the progress of climate change and its resulting impacts. Methods of mitigation include investment in renewable energy sources, carbon-neutral schemes and a reduction in carbon emissions.

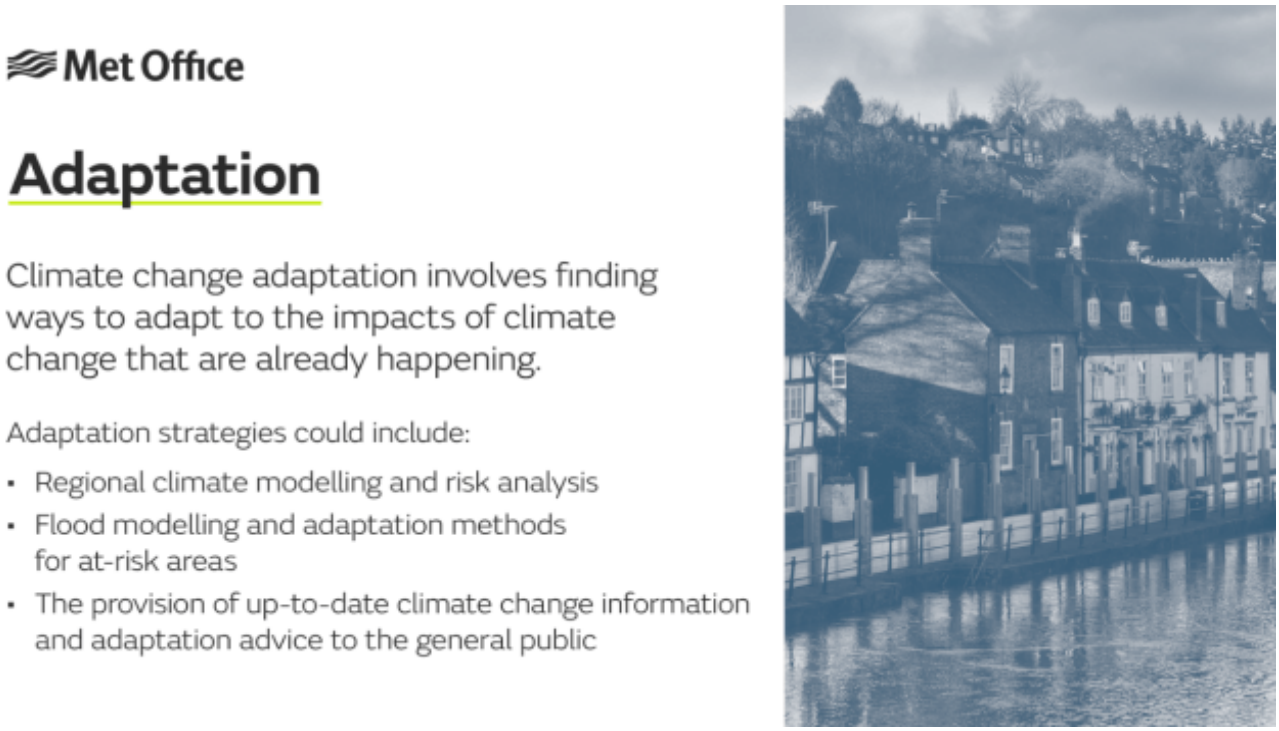

Met Office
Mitigation
Climate change mitigation involves finding ways to limit the progress of climate change and the resulting impacts that it may have.
Mitigation strategies could include:
- Investment in renewable energy sources
- Carbon neutral schemes
- Reduction of carbon emissions

Dr Helene Hewitt OBE, Met Office sea level rise expert, said, *"Without strong action to tackle climate change we could see global sea levels rise by a metre by 2100, depending on the greenhouse gas emission scenario: that could be up to five times the rate or more in the next 100 years, compared with the previous century. Even with aggressive action to cut greenhouse gas emissions, global sea levels will continue to rise."*

Climate change adaptation involves finding ways to adapt to the impacts of climate change that are already happening. Given that we are already committed to substantial future sea level rise, it is important that decision makers consider adaptation alongside mitigation in order to minimise the impacts that we experience.

Adaptation strategies should be informed by regional climate modelling and risk analysis, and flood modelling of how climate change will affect future flood risk so appropriate adaptation measures can be designed for at-risk areas. Environment Agency guidance, including Flood risk assessments: climate change allowances and Flood and coastal risk projects, schemes and strategies: climate change allowances, can be used to help with flood modelling and assessment.

Another possible nature-based adaptation strategy is managed realignment. This involves using natural coastal landforms to act as a defence against coastal erosion and flooding, as opposed to the use of artificial structures like sea walls. An example of managed realignment is the creation of "inter-tidal zones" – areas of low-lying land on the coast that are allowed to flood with the advancing tide, forming mudflats which serve to protect inland areas.


Met Office
Adaptation
Climate change adaptation involves finding ways to adapt to the impacts of climate change that are already happening.
Adaptation strategies could include:
• Regional climate modelling and risk analysis
• Flood modelling and adaptation methods for at-risk areas
• The provision of up-to-date climate change information and adaptation advice to the general public

How can the UK adapt to sea level rise?
In January 2022, the UK Government published the UK's Third Climate Change Risk Assessment (CCRA3) which sets out the risks and opportunities facing the UK from climate change. This was informed by the Climate Change Committee's independent advice report, which identified sixty-one UK-wide climate risks and opportunities cutting across multiple sectors of the economy.

Of these sixty-one risks or opportunities, the risk assessment concludes that thirty-four are ranked as 'more action needed' including risks to people, communities and buildings from coastal flooding and sea level rise.

Earlier this year, the Environment Agency published their Flood and Coastal Erosion Risk Management Strategy Roadmap to 2026 which provides a plan to deliver its strategy's vision for a nation ready for, and resilient to, flooding and coastal change – today, tomorrow and to the year 2100. The roadmap sets out the practical actions to achieve the ambitions in the strategy and tackle the growing threat of flooding from rivers, the sea and surface water as well as coastal erosion. It also delivers a host of wider benefits, including local nature recovery, carbon reduction, more integrated water management, and improved forecasting of flood events. These actions will increase our resilience to flooding events for homes, businesses and infrastructure across the country.

During August, we will be exploring the topic of sea level rise and its wider impacts, both here in the UK and from a global perspective. Follow #GetClimateReady on Twitter as we explore this theme.

Get ready for tomorrow #GetClimateReady

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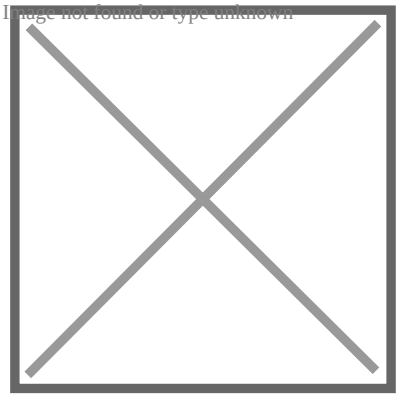


How many days of thunder do we have in the UK?

Description

The heatwave ended with a bang for many of us earlier this week as thunderstorms hit the UK after several weeks of record-breaking hot and dry weather. According to the Met Office's next generation lightning location system, there were 26,718 lightning strikes over UK land between Sunday and Wednesday, which equates to more than half of all UK lightning strikes (49,439) during the past twelve months.

These thunderstorms produced torrential downpours in some parts, leading to surface-water flooding and travel disruption, with much of the rainwater unable to permeate the hard ground. Lightning can also cause wildfires, damage to infrastructure and even fatalities. Due to these impacts, it's important to understand how frequently thunderstorms happen and how that has changed over time.

Thunderstorms can bring torrential rain leading to flooding.

How do we detect thunder and lightning?

We can calculate how far away lightning is by counting the number of seconds between the flash of lightning and the sound of thunder, and then dividing by five. That gives us the distance in miles from the lightning: 1 mile for every five seconds.

The Met Office has operated some form of long-range very low frequency lighting location network to detect and locate the source of lightning events since the 1940s. Nowadays it can obtain data about thunder and lightning from observation stations and voluntary observers, as well as from its lightning location system.

This data helps meteorologists provide warnings for the public, the aviation sector and other industries of hazardous weather associated with thunderstorms and potential impacts. But it doesn't help to determine long-term trends accurately for the whole of the UK, because of data limitations and changes to the location of sensors over time.

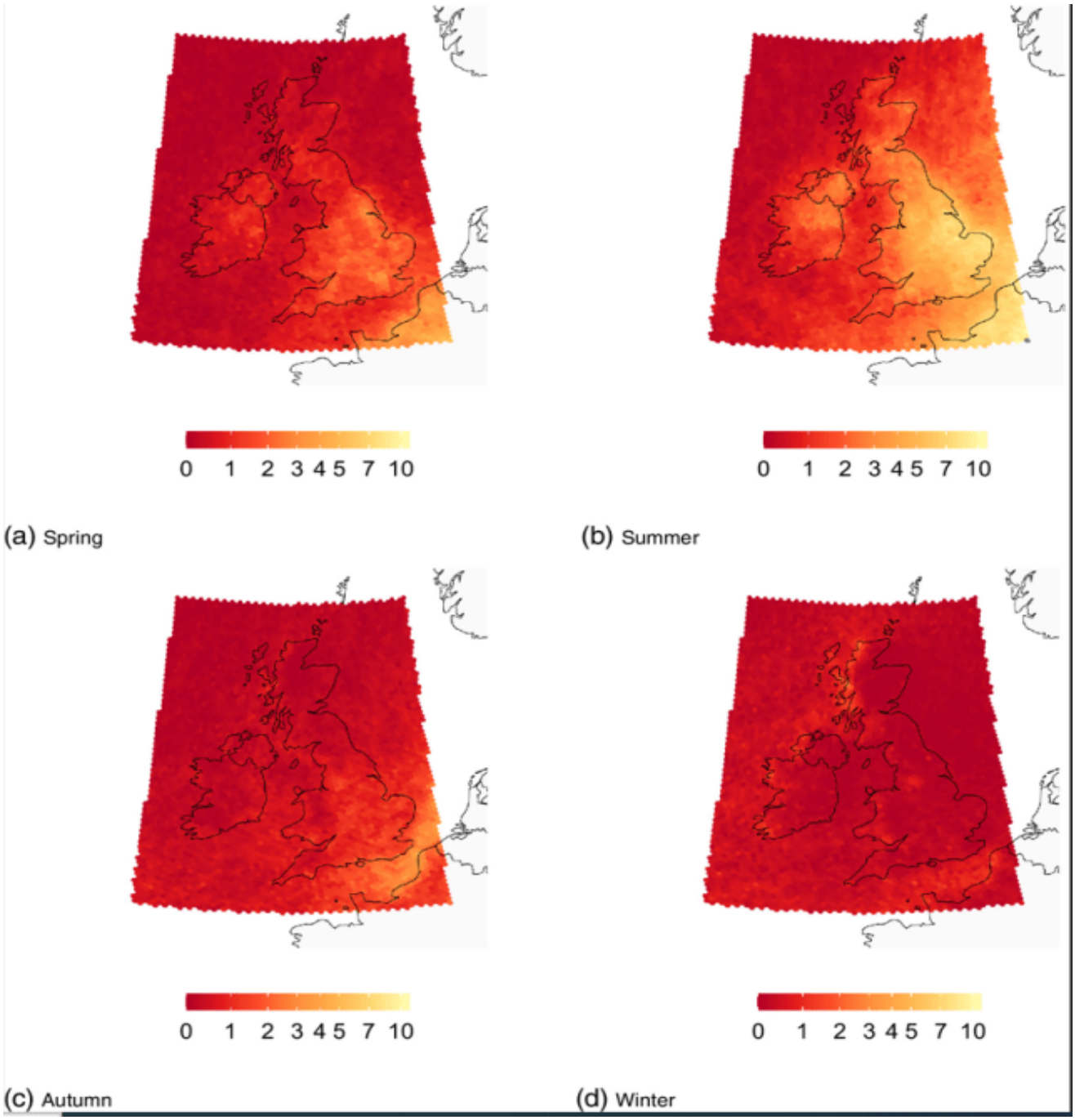
Lightning is a huge electrical discharge that flows between clouds, from a cloud to air, or from a cloud to the ground.

Days of Thunder study

The Met Office recently conducted a Days of Thunder (DoTs) climatology study to show how the frequency of thunderstorms varied over a 30-year period for the UK from 1990 to 2019 per month, season and year.

The National Climate Information Centre at the Met Office has a database of DoTs per month from volunteer observer stations, dating back to 1949. But the number of stations have varied from eight in 1949 to around 500 at its peak. The study was based on 25 stations that continuously reported DoTs between 1990 and 2019, alongside lightning location data generated from long-range lightning location networks.

The thunderstorm study introduced a new method of normalising the long-range lightning location data using observations of audible thunder. It was also the first thunderstorm study to generate a gridded dataset for such a long time period, focusing exclusively on the UK. The study could be extended beyond 2019, as more data becomes available, allowing trends to be analysed in the future.



The figure shows the 30-year average days of thunder separated by season, with the colour scales showing the number of days of thunder per year.

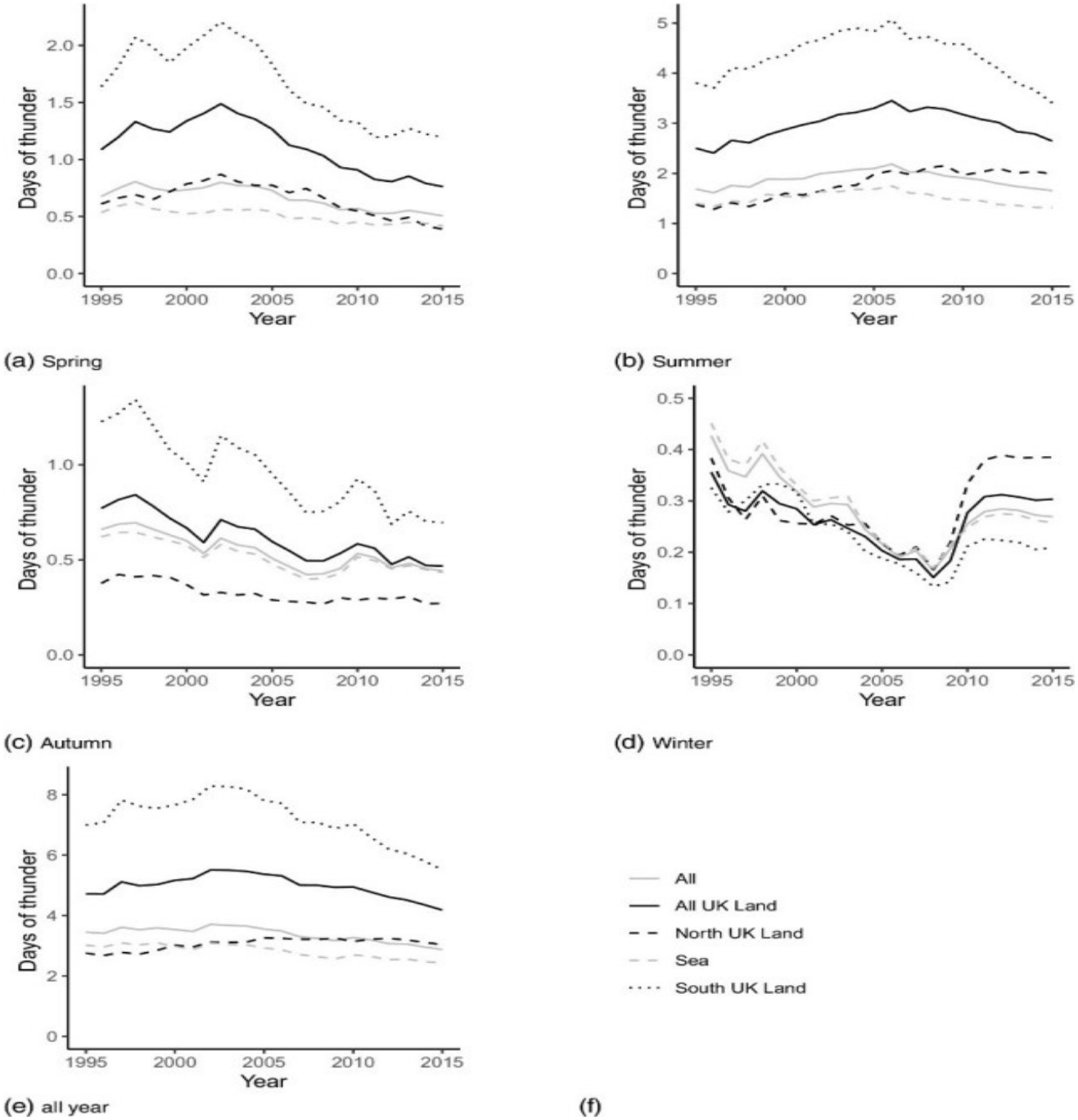
How frequently do we get thunderstorms in the UK?

Overall, there was a reduction in the number of days of thunder in the UK per year between 1989 and 2019, according to the study. Thunderstorms increased in the north of the UK and decreased in the south. Summer was the most active thunderstorm season and the winter the least active.

Met Office Observations Scientist, Ed Stone, who led the study said: “Our study has shown that in the United Kingdom we are less likely to see a thunderstorm today than we were 30 years ago. Although

we have not attempted to investigate the changes shown, is possible that some of the trends seen are due to decadal-scale oscillations in the atmosphere.

“The findings may also help us to predict future lightning activity as part of climate change. We hope that the methods presented can support significant further research using other climatological data.”



These graphs show how the average number of days of thunder has changed during the 30-year period year. The solid grey line is UK land and sea area; the solid black line is all UK land area, and the dashed grey line is UK sea area. The black dotted line and black dashed line are south UK Land and North UK Land area respectively.

What is the relationship between lightning and climate?

The relationship between lightning and climate change is still being studied by climate and weather scientists. A Science study in 2014 predicted that global warming will increase the frequency of lightning strikes by about 12% for every degree rise in global temperature.

Between the two 30-year periods 1961-1990 and 1991-2020, the mean temperature of the UK rose by 0.8C from 8.3C to 9.1C. Scientists will need to undertake further research to understand why the increase in the UK's mean temperature appears not to have led to a corresponding increase in lightning activity; in contrast to the 2014 study.

Ed Stone of the Met Office added: "Thunderstorms are among the most impactful elements of weather in the UK. Understanding more about their frequency has important implications for increasing our knowledge of future climate change and severe weather events."

Date Created
August 2022

Future summers could last longer hints Met Office research

Description

A Small White butterfly enjoys the autumn sunshine. Picture: Grahame Madge

UK autumns are likely to become drier on average and more ‘summer-like’ with increasing climate change according to new research from the Met Office.

Daniel Cotterill is the lead scientist behind the study, which focusses on the projected likelihood of occurrence of weather patterns, of which there are 30 standard types. He said: “Each weather pattern over the UK brings certain characteristics, whether that’s rainfall or temperature.

“Using climate models and the UK Climate Projections, our research found that the largely ‘summer-like’ weather patterns -bringing drier conditions – will begin to extend into the start of autumn. And weather patterns such as those dominated by large low-pressure systems, will tend to occur slightly less in autumn in future.

“Although we don’t expect to see this shift in pattern imminently, a key finding from this study is that from the mid-2020s warmer and drier autumns following hotter and drier summers could increase drought risk.”

The strength of the shift in weather patterns is dependent upon the rate of greenhouse gas emissions are emitted into the atmosphere. Climate scientists refer to these different rates as emissions' pathways. Daniel added: "Our research compares a very low-emissions pathway to a very high-emission scenario. What we see is these effects are a lot stronger in the high-emissions scenarios, and this suggests that these changes in weather patterns are due to human influence and the resulting effect of warming on atmospheric circulation."

The study shows that we're likely going to see less rain in autumn on average. But, backing up other studies, it signalled the potential for extreme rainfall events to be interspersed between the drier spells.

Daniel added: "This is a signal we'll start to perhaps see over the next ten years. We're likely to see a 4 to 12% reduction in rainfall in English regions in the future in autumn. And this depends very much on the greenhouse gas emission scenarios. One of the things we are already seeing in autumn as average seasonal temperatures rise is an increase in the number of extreme rainfall events. But in future, we're likely to see this drying effect as well.

"UK Climate Projections have shown for some time that we can expect hotter, drier summers and warmer and wetter winters. Our study shows we are likely to see hotter and drier autumns on average too.

Daniel added: "To see how situations might unfold we could consider the autumn of 2020. On 3 October we saw the UK's wettest day on record and the volume of rainfall which fell on the UK that day could have filled Loch Ness. However, if you look at the overall rainfall for that autumn, it's actually only 6% above average and that is because of a drier September and November that year."

The paper – *Future extension of the UK summer and its impact on autumn precipitation* – is published in the journal Climate Dynamics.

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Pakistan flooding – ‘worst’ in decades

Description

Relentless monsoon rain has left 33 million people across Pakistan affected by flooding, according to Pakistan’s Federal Minister for Climate Change, Senator Sherry Rehman. Although very little rain is expected through the coming weeks the levels of the Indus and Kabul Rivers will continue to leave many lives and livelihoods at risk.

The Asian summer monsoon season runs from June to the end of September, and much of south Asia depend on this rainfall following the dry season. However, this year Pakistan has seen this rain come in unmanageable volumes.

Deputy Chief Meteorologist at the Met Office, Ele Hands, said: “Pakistan started the season with its wettest July on record, followed by a very wet August. These added together means that they have already seen three times the average monsoon rainfall, and more locally areas have received up to five times the amount of rain they would usually see, and we still have another month of the monsoon season left.”

River levels are slowly retreating from that of a 1 in 100-year event, very little rainfall is expected this week, but levels are forecast to be that of a 1 in 20-year event even into this weekend.

The Indus River rises in Tibetan Plateau, while the Kabul River rises in the Hindu Kush mountains in Afghanistan. The Indus drains an enormous area of Pakistan, and extreme rainfall has resulted in the main river channel becoming overwhelmed. Mountain glaciers to the north feed these large rivers flowing south, and during mid-July to mid-August peak snow melt and rainfall coincide to result in the highest river levels.

The River Indus is one of south Asia’s great rivers. In normal times this natural artery brings much-needed water from mountain ranges in the north to a swathe of Pakistan. Picture: Shutterstock

The drivers of flooding

Throughout July and August, a succession of monsoon depressions tracked west across India and into Pakistan bringing waves of very heavy rain. This weather pattern is typical during monsoon season, but the frequency has changed this year.

Monsoon conditions are driven by a simple mechanism that drive a dramatic change, every year. Heat builds up across the Tibetan Plateau through the spring and summer months causing air to rise. This means low-pressure depressions develop at the surface. These depressions drag in moist southwesterly air which lead to heavy rainfall.

Ele explained: “In a typical monsoon season, we would expect around four waves of this heavy rain but there have been eight of them so far. These waves have moved into a similar area each time and that means the rain has accumulated over the same areas.”

Not only have these pulses of rain arrived at an unmanageable rate, but they have also pushed into more northern parts of Pakistan. The increase in spatial coverage means that far more people compared to usual as well as other extreme monsoons events, have been affected.

Is this climate change?

The south Asian monsoon is known to exhibit a high degree of natural variation with some extreme years producing much higher rainfall totals across the region, and the ongoing La Nina conditions are likely to be a contributing factor to the wetter-than-average season.

The natural variability creates challenges for climate scientists trying to examine the impacts of climate change on this weather system. This is largely because the differences between extreme wet and dry years can be larger than any influence that could be expected from climate change at this stage.

We know that a warmer atmosphere holds more moisture, so this could be a contributing factor affecting those years which would already have been extremely wet. It is likely human influence has led to intensification of heavy precipitation across Asia but adding glacial and snow melt into the picture complicates the relationship between the south Asian monsoon and downstream flooding events. Any changes in land management of the catchments of southern Asia’s great rivers provides an extra complication which needs to be considered. Ongoing research into the evolution of the Indian Summer Monsoon is therefore vital to better understand what the future holds.

Impacts

In 2010, an extreme monsoon caused devastating flooding to the Indus River in Pakistan. It was estimated that 20 million people were affected, so far, the 2022 monsoon has affected 33 million people. Human fatalities are currently estimated to be around 1000, so far less than the total from 2010. But the impacts from this year’s monsoon season are expected to continue well after the peak rainfall, as the rivers continue to react.

Flooding is always expected during monsoon season but this year’s flooding will leave damage that will

take years to recover from. UN (United Nations) Secretary General Antonio Guterres has said “the people of Pakistan face the unrelenting impact of heavy rains and flooding – worst in decades.” On Tuesday, the Government of Pakistan and the United Nations launched a Floods Response Plan in the backdrop of devastating rains, floods, and landslides that have destroyed homes, caused over 735,000 livestock to perish, impacted two million acres of crops, and caused severe damage to communications infrastructure.

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